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SUMMARY OF THE REPORT OF THE WORKING GROUP ON AIR QUALITY IN THE TORONTO SUBWAY SYSTEM

ARB-TDA-Report No. 13-80

MARCH 1980

Ontario

Ministry of the Environment

Ministry of Labour

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ONTARIO MINISTRY OF THE ENVIRONMENT
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TORONTO TRANSIT COMMISSION

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FOREWORD

This document is a technical summary of the final report of the Working Group on Air Quality in the Toronto Subway System.

The Working Group was formed in August 1976 to direct studies of air quality in the subway system, to evaluate the results with regard to health effects on both passengers and subway employees, and to recommend and oversee any necessary abatement measures.

The Working Group's studies were conducted between October 1976 and December 1979. These included air quality studies on the Yonge-University and Bloor-Danforth sections of the Toronto subway system between October 1976 and April 1978. The Spadina section of the system was not opened until January 1978 and was not included in the air quality studies. An abatement program recommended by the Working Group has been undertaken by the TTC and continues to the present.

To the knowledge of the Working Group, its studies are the most exhaustive of any reported to date in a subway transit system.

The full report of the Working Group is available from:

Ontario Government Bookstore

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MAIN CONCLUSION

The most important conclusion reached by the Working Group is that there is no discernible health hazard either to TTC employees or to passengers due to the contaminants that are found in subway air, although subway passengers were found to be exposed to higher levels of airborne particulate matter than the general public in Toronto.

BACKGROUND AND OBJECTIVES

Formation of the Working Group in August 1976 was prompted by the results of surveys conducted by the Ministry of the Environment in May 1975 and April 1976 that showed asbestos and airborne dust to be generally higher in the enclosed spaces of the Toronto subway system than in the ambient air outside the system. On the basis of these findings, it was decided that an intensive study of the general air quality of the subway system should be undertaken with emphasis upon suspended particulate matter (airborne dust particles) in general and asbestos and lead in particular.

The objectives of the study were as follows:

1. to determine the sources of particulate emissions into subway air;
2. to determine whether the degree of contamination of subway air was creating a potentially harmful human exposure;
3. to determine which abatement measures would lead to reduced emissions and improved air quality.

SUSPECTED SOURCES OF CONTAMINANTS

Contaminant emissions within the subway system arise from the normal wear of materials caused by friction and wind erosion. Such emissions, it was suspected, were resulting mainly from the following processes:

1. friction between car wheels and track rails and at third-rail power contacts;
2. friction between brake shoes and car wheels during the braking processes;
3. wind erosion of tunnel facing or lining material

STUDY ORGANIZATION

The study consisted of a number of investigations of air quality, human exposure, and equipment operating and emissions characteristics, and it was conducted in three separate but interrelated test programs:

1. Air Quality Test Program
2. Occupational Health Test Program
3. Materials and Equipment Test Program

The investigations of the Air Quality and Occupational Health Test Programs were conducted largely together in two stages. The first stage was a comprehensive survey carried out in the subway system in October 1976, and its purpose was twofold: 1) to determine the contaminants present in the subway, their sources, and the degree of public exposure; 2) to provide direction for the development of second-stage investigations.

The second stage, in accordance with this strategy, consisted of a number of follow-up investigations and tests undertaken 1) to evaluate the effectiveness of certain abatement measures, 2) to achieve a more accurate determination of emission sources, and 3) to determine employee health risk.

The investigations of the Materials and Equipment Test Program were conducted in conjunction with those of the other two programs. Analysis of brake shoes and tunnel lining materials were performed to estimate their emission potentials for asbestos, lead, and other possible components of suspended particulate matter. Substitute brake shoe materials were evaluated within an ongoing TTC materials test program that was begun in 1975 and is still continuing.

AIR QUALITY TEST PROGRAM

Test Program Outline

The major requirement of the air quality portion of the October 1976 survey of the subway system was to determine which contaminants were present in the system and in what concentration. Towards this end, measuring instruments were placed in selected subway tunnels, near station platforms, in several ventilation shafts to the street, and on-board trains running through the system. Of particular interest were the following contaminants: 1) asbestos fibres, 2) suspended particulate matter or dust, 3) lead

The follow-up portion of the air quality test program was conducted in 1977, and it was divided into three phases:

1. monitoring the effect of tunnel wall washing as a method of controlling the concentrations of suspended particulates during service;
2. monitoring total suspended particulate concentrations during periods of exclusive use of each of the two basic types of subway cars to try to determine the relative difference in braking emissions;
3. measuring passenger exposure by on-train sampling of suspended particles.

Asbestos

Asbestos fibre concentrations (i.e., amounts present in specified volumes of air) are expressed in two ways:

1. by fibre count (total number of fibres per millilitre of air or number of fibres greater than 5 micrometres in length per millilitre of air);
2. by fibre weight (micrograms per cubic metre of air).

Ontario's desirable ambient air quality guideline for asbestos fibres is 0.04 f/ml ($>$5um in length) averaged over any 24-hour period. The province's recommended standard for occupational exposure to asbestos fibres is 2 f/ml ($>$5um in length) averaged over any 8-hour working shift out of a 40-hour work week. The criterion of "greater than 5 micrometres in length" arises from considerations of medical evidence and measurement technique in the development of the British Occupational Hygiene Society's standard, upon which the Ontario value is based.

During the October 1976 survey, measurements for asbestos fibres were conducted over periods of time that ranged from two to three hours in length. This period was chosen on the basis that very few members of the public would spend more than two hours per day in the subway system.

The results of the survey for asbestos showed the presence of chrysotile asbestos fibres throughout the subway system in concentrations similar to those found in preliminary May 1975 and April 1976 surveys. The highest concentrations were found on the Yonge and University sections of the system. The concentrations ranged from below 0.002 fibres greater than 5 micrometres in length per millilitre (0.002 f/ml($>$ 5um)) to a high of 0.3 fibres greater than 5 micrometres in length per millilitre (0.3 f/ml($>$5um)) averaged over two to three hours.

At the time of the May 1975 and April 1976 surveys, concern was raised over the fact that some of the concentrations measured were above Ontario's ambient air (environmental) guideline.

The highest concentration of asbestos recorded in the October 1976 survey (0.3 f/ml($>$5um)) was also higher than the environmental guideline (which was exceeded in 13 of 52 cases), but much lower than the occupational standard.

The Working Group assessed the effect of exposure to these concentrations of asbestos fibres by considering the dose that would be received by a passenger riding the subway for a maximum to two hours. The effect of exposure is related to the amount of asbestos inhaled. The amount of asbestos that a subway passenger would take in during a two-hour stay in the subway by breathing air containing the maximum level of asbestos quoted above (0.3 f/ml) would be less than that taken in by breathing ambient air containing the guideline level of 0.04 f/ml over 24 hours.

Two important points should be noted: 1) typical ambient air concentrations of asbestos measured in Toronto are well below the 0.04 f/ml guideline and 2) most of the concentrations of asbestos fibres measured in the subway were well below the maximum measured value of 0.3 f/ml. On the basis of these facts and considerations, the Working group found that asbestos concentrations in subway air, at the time of the air quality studies, were acceptable.

On balance, there is no evidence to suggest that exposures to chrysotile asbestos such as those measured in the Toronto subway in October 1976 would have a deleterious health effect on passengers. However, it is still extremely important that asbestos levels be kept as low as can possibly be achieved. In 1980, in fact, it is expected that the levels of asbestos (as well as of other contaminants) are substantially lower in the subway system than they were in 1976 because of the abatement program undertaken by the Toronto Transit Commission, in which brake shoes were replaced by a type with an extended life (lower emissions).

A follow-up survey recommended for 1980 will indicate whether the expected reductions have been achieved.

Friction between brake shoes and car wheels was the major source of asbestos fibres in the subway system rather than wind erosion

of tunnel lining materials. This conclusion was based on the following two considerations:

1. Total asbestos fibre concentrations were comparable both in areas of the subway where the tunnel lining contained asbestos fibres and where it did not.
2. Very short fibre lengths of the type found in brake shoes dominated the collected asbestos samples in contrast to the very long fibres found in the acoustic insulation that contained asbestos.

Suspended Particulate Matter

Measurements from the October 1976 survey confirmed high levels of suspended particulate matter or airborne dust particles to be present in the subway system, particularly in the Yonge and University sections.

Samples collected over periods of 18 to 24 hours showed concentrations for subway air ranging from 148 micrograms per cubic metre (148 ug/m^3) to 2267 micrograms per cubic metre (2267 ug/m^3), as compared to Ontario's desirable ambient (outside) air quality criterion of 120 ug/m^3 averaged over 24 hours. Although high, these levels should not pose a health threat to passengers using the system for only up to two hours a day, this assumption being based on the reasoning stated earlier respecting the total amount of asbestos inhaled in the subway relative to ambient air levels.

Analysis of other samples (taken from ventilation vents) showed that ambient air entering the system was not responsible for the elevated dust levels; measurements of contaminants flowing out of the vents greatly exceeded measurements of contaminants being sucked into the vents.

Chemical analysis of the total suspended particulate matter (TSP) showed that approximately half of the material consisted of iron--the result primarily of friction between car wheels and track rails. Other elements present in elevated

concentrations were lead (about 3 per cent) and carbon (about 8 per cent). In comparison, asbestos comprised less than 0.1 per cent of the TSP by weight.

Both lead and carbon were present in the brake shoes from which, it is assumed, they were released during the braking process. This assumption is borne out by the fact that concentrations of TSP were heavier on the North Yonge and University sections of the system where heavy braking is also required. Lesser contamination from brake shoe emissions occurred on the Lower Yonge section; much less on the Bloor-Danforth section.

Lead

During the October 1976 survey, sampling for lead over periods of 18 to 24 hours indicated an average level of 56.4 micrograms per cubic metre of air (56.4 ug/m^3) on the Yonge-University line. This level is well above Ontario's desirable ambient air quality criterion of 5 ug/m^3 over 24 hours. The highest sampling result was 93.7 ug/m^3.

Based on the above average (56.4 ug/m^3) and a number of other assumptions, including two hours of travel per day on the Yonge-University line, an attempt was made to calculate what the highest blood lead levels of subway users might be in comparison to non-subway users.

The calculated, theoretical results generally indicated that blood lead levels of regular users of the Yonge-University line might be as high as 40 ug Pb/100ml of blood after 25 years of exposure. In order to test whether these model predictions were valid, it was decided to test the actual blood lead levels of the group of individuals most heavily exposed to lead in the subway system--TTC employees.

The testing of 24 TTC long-term subway employees in April 1978 indicated an average blood lead level of 12.8 ug/100 ml; the highest blood lead level was 21 ug/100ml. Both the approximated blood lead levels for subway users and the actually measured blood lead levels for subway workers were below the levels at which health would be affected.

70-80 ug Pb/100ml of blood is generally considered to be the level at which symptoms of lead poisoning might appear.

It should be pointed out that, for some reason, either the theoretical model overestimated the blood lead levels, or the measured levels overestimated the actual level of exposure.

Iron and Carbon

The iron and carbon levels found in the surveys do not pose health problems for subway users or workers. There is no evidence that the inhalation of relatively large iron particles is harmful. The percentages of carbon (presumably largely graphite) that were found in the total suspended particulate matter were well below the levels at which the respiratory system might be effected.

Follow-up Testing

Special night-time wall washings, in addition to the TTC's regular wall washing program, were conducted in two areas of the Yonge-University line in February 1977 to determine if the removal of settled dust in this manner had a lowering effect on dust levels measured during regular operations. Monitoring before and after wall washings, however, when trains were in service, showed little difference in airborne dust concentrations subsequently.

Track-side monitoring was conducted in April/May 1977 to determine the relative brake-shoe emissions of the two major types of subway cars--the older Gloucester ('G') car equipped with only a mechanical braking system and the newer Montreal ('M') and Hawker-Siddeley ('H') cars equipped with a dual mechanical/electrodynamic braking system.

Against a regular service pattern involving a mix of 'G' and 'H' cars on the Yonge-University line, exclusive 'G' car use produced a 30 per cent dust-level increase, while exclusive 'H' car use produced a 39 per cent dust-level decrease. Altogether, tests indicated that 'G' cars were producing three times as much particulate matter as 'M' and 'H' cars--the result of greater brake wear. 'G' cars have more mechanical brakes than 'H' and 'M' cars, and they need to be applied for longer periods of time during the braking process.

Comparative on-board dust-level testing of 'G' and 'H' cars in August 1977 indicated that the 'H' car was producing 33 per cent less dust, 45 per cent less lead, 38 per cent less iron, and 20 per cent less carbon than the 'G' car.

Follow-up air quality testing confirmed that trains were primarily responsible for contaminant emissions in the subway system; that train braking systems were a major source of particulate emissions; that brake emissions were substantially higher from 'G' cars than from 'H' cars; and that air quality in cars was similar to air quality in tunnels and on station platforms.

OCCUPATIONAL HEALTH TEST PROGRAM

The Occupational Health Test Program consisted of two parts:

1. sampling of the "breathing-zone" air of the TTC employees in various work situations and MOL technical staff riding on trains as passengers;
2. blood testing of TTC employees for lead levels

The breathing-zone air of an individual is that portion of the air surrounding the upper part of the body, and it can be tested by a special portable sampling pump and lapel filter cassette carried about during normal working-day activities.

Two breathing-zone air samplings were conducted during the study, both involving TTC employees in station, track, and train operation duty areas and MOL technicians riding the system as passengers.

The first sampling was conducted as part of the comprehensive field survey in October 1976 and was directed at assessing the exposure of TTC employees and subway passengers to fibrous dust (possibly containing asbestos). The second sampling was undertaken in September 1977 to assess exposure to other constituents of suspended particulate matter.

Results of the October 1976 survey indicated fibrous dust concentrations ranging between less than 0.04 and 0.21 fibres greater than 5 micrometres in length per millilitre (<0.04 - 0.21 f/ml (>5um)). In addition, analysis revealed that no amphibole asbestos fibres (>5um) were present in the samples. The Ontario standard for exposure to chrysotile asbestos is 2.0 f/ml (>5 um), and to amphibole asbestos 0.2 f/ml (>5um).

The September 1977 sampling for other constituents of suspended particulate matter or dust indicated the following substances to be present: chromium, iron (as an oxide), lead, manganese, nickel, and zinc (as an oxide). However, the Ontario guidelines for these substances were exceeded only for lead in two out of 30 samples taken. Both samples were obtained from the same trackman working in the lower Yonge section of the subway system. The trackman's blood lead level was later determined to be well below the average of the representative TTC employee group sampled for blood lead levels in April 1978. As indicated earlier in this report, the blood lead levels of all TTC employees tested were found to be well below levels at which health would begin to be affected.

MATERIALS AND EQUIPMENT TEST PROGRAM

A number of tests were conducted in and out of the subway during the course of the study to determine how contaminant emissions might be reduced in the system.

Wall washing, as already indicated in this report, had no appreciable effect on dust levels; nor did the operation of ventilation fans on a 24-hour basis, as was done in a special test at two stations on the Yonge-University line.

Samples of acoustic lining from representative subway areas were analyzed for content, particularly for asbestos. Several different makes of acoustic materials are used through the system, not all of which contain asbestos. As indicated earlier in this report, it was concluded that asbestos fibres were being emitted into the subway system mainly as a result of brake shoe friction, not tunnel lining erosion.

The one aspect of materials and equipment testing that came to offer significant potential for reducing contaminant emissions was brake shoe testing and analysis.

The Toronto Transit Commission has been working since 1975 to reduce brake shoe emissions. The process has consisted of testing various makes of brake shoes developed by manufacturers for this purpose.

At the time of the October 1976 survey, most of the 'M' and 'H' cars in the subway fleet had been equipped with the Cobra W-392 brake shoe, the least contaminant-emitting brake shoe then available that also met performance specifications. The 134 'G' cars, on the other hand, remained equipped with an older and more contaminant-emitting brake shoe (Anchor), pending the conversion of brake shoe mountings that would allow them to be equipped with the Cobra W-392 brake shoe.

This conversion began in 1977, and, by the end of 1979, all 'G' cars had been equipped with the Cobra W-392 brake shoe; which wears nearly twice as long as the Anchor shoe and contains practically no lead. The Cobra W-392 brake shoe does contain approximately the same amount of asbestos as the older brake shoe; however the TTC is now evaluating a lead and asbestos-free brake shoe, and they report that considerable progress is being made.

EFFECT OF ABATEMENT MEASURES

Replacement of the Anchor shoe with the Cobra shoe on 'G' cars will have considerably reduced contaminant emissions in the subway system. The following are the projected reductions in contaminant levels due to reductions in brake shoe emissions that have occurred between 1976/77 and 1980 for the Yonge-University-Spadina line:

- a 30 to 50 per cent decrease in dust levels;
- a 50 per cent decrease in asbestos levels;
- a 90 per cent decrease in lead levels;

An indirect measure of abatement has also been achieved with the opening of the Spadina section of the Yonge-University-Spadina line, which has helped to improve the air quality of the Yonge and University sections of the line. This improvement arises from the fact that the additional cars acquired to meet increased fleet demands are of the new 'H'-type. The proportion of 'G'-type cars in the system has been reduced and so has the relative contribution of their brake shoe emissions.

As recommended in this report, additional monitoring should be undertaken in order to determine and verify the actual contaminant concentrations now being experienced in the Toronto subway system.

SUMMARY OF FINDINGS/CONCLUSIONS

The Working Group on Air Quality in the Toronto Subway System has reached the following conclusions:

1. There is no discernible health hazard either to TTC employees or to passengers due to the contaminants that are found in subway air, although subway passengers were found to be exposed to higher levels of airborne particulate matter than the general public in Toronto.

   Total suspended particulate matter and its components, lead and asbestos, were the air contaminants singled out for special attention because of their potential to cause adverse health effects.

2. The measured levels of contaminants were assessed relative to existing Ontario Environmental Air Quality Criteria or Guidelines and Occupational Health Guidelines for all of the detected components of airborne particulate matter that were of concern. The conclusion that there is no discernible health hazard to passengers (1 above) is based upon consideration of measured levels relative to the criteria or guidelines and of the short-term exposure of subway passengers relative to the 24-hour exposures upon which the environmental criteria or guidelines are based.

   The conclusion respecting employees (1 above) is based upon normal application of the occupational health guidelines for worker exposure, supported by biological monitoring.

3. The predominant emissions of particulate matter in the subway system are due to normal wear of brake shoes, subway car wheels, and rails. Brake shoe emissions comprise approximately one-half of measured airborne particulate matter. The greatest quantity of brake shoe emissions is given off by the original Gloucester ('G') cars, which are currently in use only on the Yonge-University-Spadina line.

4. Measured levels of pollutants are greater in those sections of the system on which 'G' cars are used, and where heavy braking is required, namely, the North Yonge and University sections. Lesser contamination from brake shoe emissions occurs in the Lower Yonge section. Much less contamination was found in the Bloor-Danforth section. The air quality studies covered by this report were completed before the Spadina section opened (January 1978), so that the report contains no data relating specifically to air quality in that portion of the subway system.

5. A significant reduction in particulate emissions has been achieved by converting the brake shoes of the 'G' cars to a type that (a) wears nearly twice as long as the older type and (b) contains practically no lead. All of the 134-car 'G' fleet had been converted as of the end of 1979.

6. The opening of the Spadina section has helped to improve the air quality of the Yonge and University sections. This improvement arises from the fact that the additional cars acquired to meet increased fleet demands are of the new 'H' type. The proportion of 'G'-type cars in the system has been reduced and so has the relative contribution of their brake shoe particulate emissions.

RECOMMENDATIONS

The Working Group makes the following recommendations, based on the results of its studies and other available information:

1) Although there are no current or imminent health hazards that may be attributed to airborne contaminants in the subway system at the concentrations that have been measured, action to reduce the concentrations of lead, asbestos and suspended particulate matter in subway air should continue. This action will improve subway air quality for both passengers and employees.

2) The abatement objectives for all contaminants should be to reduce typical levels on the Yonge-University-Spadina line to levels similar to those found currently on the Bloor-Danforth line as soon as is practicable, using the best available technology.

3) Implementation of a specific abatement program to achieve the objective set out above should be continued by the TTC in accordance with Ministry of the Environment guidelines.

4) Air quality in the subway should be monitored regularly by the TTC at one or more sites, in co-operation with the Ministry of the Environment.

5) Progress on the continuing abatement program and monitoring should be reported at the end of 1980 and the report made public.

6) Although TTC employees are not being exposed to high levels of asbestos and lead, it is recommended that periodic personal monitoring of TTC employees, utilizing individual (personal) air quality monitoring equipment, be carried out in accordance with Ministry of Labour guidelines.

7) The Working Group should be disbanded with the publication of its final report.